BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 10066

SUBJECT: Implementation of an Intelsat IV Terminal on the SWS (Apollo Applications -1) - Case 620

DATE: October 22, 1969

FROM: R. L. Selden

MEMORANDUM FOR FILE

A communications satellite terminal has been tentatively approved for installation on the Saturn Workshop (SWS). This terminal will provide voice and data between the Earth and the SWS using the Intelsat IV communications satellite as a relay. This note provides options on the implementation of this terminal; these options cover the desired configuration as well as others that are felt to be cheaper to implement. Tentatively identified as required communications functions are: 1) duplex voice, 2) updata, and 3) three modes of down link telemetry including a) 72 kbps (ATM real time telemetry), b) 51.2 kbps (AM or CSM real time telemetry), and c) 1.6, 4.0, and three 5.12 kbps bit streams simultaneously (these represent the inputs to the various orbital assembly tape recorders). These three data modes are to be provided one at a time simultaneously with two-way voice and up data.

For the purposes of this memorandum, the terminal to be implemented on the SWS is assumed to consist of an 11 foot diameter antenna and a 20-40 watt transmitter for each link to be transmitted. Preliminary investigations on modulation techniques show a simpler and probably more efficient system is one using two rf carriers to and from the SWS. The two up links provide voice on one carrier and up data on the second; the two down links similarly provide voice on one carrier and telemetry on the second. In addition to obviating multiplexing and demultiplexing associated with the use of a single carrier, this arrangement could provide inherent redundancy if the transmitters and receivers are implemented to handle either voice or data. Also assumed is a two band capability for each transmitter and receiver. That is in the event of failure of the normal Intelsat IV transponder, the terminal on the SWS can be switched to operate with another Intelsat transponder that will have been designated by Comsat prior to the mission. This capability also enhances the terminal reliability and provides for an Intelsat IV failure. It is envisioned that this dual frequency band capability could be implemented with two sets of

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ABSTRACT

A brief description of the proposed communications terminal that would allow relay of voice and data between the Saturn Workshop and Earth using the Intelsat IV Communications Satellite is presented. Alternatives to the proposed system, that appear less costly to implement, are presented for consideration in determining the final cost and schedule impact associated with the development of the terminal for AAP-1. These alternatives include providing voice from one point only in the Orbital Assembly (OA) as opposed to interfacing with the OA audio hardline system; reduction in the number of data modes by eliminating some of the bit streams that interface with the terminal and iterating on the terminal design parameters, for example, antenna size, transmitter powers and multiplexing and modulation methods, as a function of cost.

crystals for each receiver and transmitter and possibly two band pass filters for the transmitters. The terminal then would consist of two receivers, two transmitters with 25 watts nominal output power and an 11 foot antenna. Reference 1 provides assumed modulation techniques and terminal requirements for the first two telemetry modes mentioned earlier (51.2 or 72 kbps in conjunction with up data and duplex voice) as well as the voice and up data link.

The third mode (5 low rate bit streams) has not until now been evaluated. There are two possible multiplexing techniques namely time division multiplexing (TDM), i.e. (1) combining all five bit streams into one and transmitting at approximately 25 kbps, or (2) frequency division multiplexing where each bit stream modulates its own subcarrier and then the summation of the five subcarriers modulates the rf carrier. If TDM is used, it is obvious that the proposed terminal in Reference 1 is sufficient. If FDM is used, this is not so obvious.

Two approaches are possible with the FDM method - one would be to use standard IRIG subcarriers and transmit in a PCM/FM/FM or PCM/PM/FM mode or use non standard subcarriers and transmit in a PCM/PM/FM mode. FM is proposed as the rf carrier modulation because of its lessor impact at the Intelsat Earth station. (They already have FM receivers, however it is proposed to use PM for the high rate channels which will require at least a new demodulator.) Assuming the use of IRIG subcarriers and attempting to minimize the baseband bandwidth leads to the baseband structure shown in Table I.

TABLE I - AAP - INTELSAT IV
DATA MODE 3 - BASEBAND SIGNAL DESIGN

Bit Stream Rate	Source	Subcarrier	Subcarrier Bandwidth	IRIG Channel
5.12 kbps	AM T/R Input	Baseband	N/A	N/A
1.6 kbps	CSM Low Rate	10.5 kHz	1575 Hz	12
4.0 kbps	ATM T/R Input	30.0 kHz	4500 Hz	15
5.12 kbps	AM T/R Input	40.0 kHz	6000 Hz	16
5.12 kbps	AM T/R Input	52.5 kHz	7875 Hz	17

It is apparent from Table I, even without any rigorous calculations that a minimum channel requirement would be something like 10 dB in a bandwidth of 150 kHz or greater. 10 dB is required to operate the Earth station demodulator at threshold or above and 150 kHz required as a minimum rf bandwidth to pass the IRIG channel 17 subcarrier. This can be translated to a C/N_o of at least 61.8 dB-Hz. This is 2 dB more than is indicated in Reference 1 for the 72 kbps channel requirements and this does not include any margin. (This implies a transmitter power increase to 50 watts or an antenna diameter increase to about 16 feet.) Using new subcarrier frequencies in a PCM/PM/FM mode theoretically might reduce this requirement by 3 dB; however a very cursory evaluation of a mode of this type shows little or no improvement.

Although the use of TDM is very attractive, experience with the PCM interface box of the AM, indicates that the cost of the time division approach could be very expensive. It may be from cost arguments that we want to forego the combined low rate mode and transmit only one or two low rate bit streams at a time.

Implementation of each of these communications functions will probably impact schedule and cost more than the rf portion of the terminal (e.g. antenna, transmitters and receivers). In the remainder of this memorandum, methods of implementation are discussed.

Voice

It is desirable to integrate the voice transmitted from the Intelsat terminal with the hardline voice system to be provided throughout the OA. It is recognized that this could be somewhat expensive and could possible lead to a new audio center somewhere in the OA to provide the interface and controls for the terminal. An alternate and cheaper approach may be to provide voice to the Intelsat terminal from only one location that is independent of the normal OA voice intercom system.

Up Data

It is proposed that the link to the OA providing up data be modulated with the one and two kilohertz tones and that the interface with the AM (only) up data system be that which normally exists between a UHF command receiver and the up data link equipment. Other alternatives are possible but do not seem to be as attractive in the design of the system for this function.

Telemetry

Three down link telemetry modes have been tentatively identified for transmission from the OA. It is recommended that costs associated with each be identified separately. For example, it may be simple to transmit AM telemetry if the terminal control were in the AM, but much more difficult and expensive to make available telemetry from the ATM and the CSM. It is also recommended that the need for data mode 3 be reevaluated because of the implied difficulty in implementation. Rather than a complete deletion, it may be simpler to transmit one or two low rate bit streams at a time in lieu of all five. The transmission of one bit stream, for example 51.2 kbps from the AM, would probably be sufficient to provide a good operational demonstration of the use of Intelsat IV as a relay satellite.

Conclusions

Several ways of implementing a communications terminal on the SWS (AAP-1) to work with an Intelsat IV communications satellite have been discussed. To provide a fully integrated terminal (particularly voice and telemetry) looks to be potentially very expensive. In determining cost and schedule impacts, alternative configurations should be evaluated. These include:

1) Varying antenna sizes

2) Making the voice capability from the terminal independent from the OA audio intercom system

3) Providing fewer data modes than have been tentatively identified as required

4) Reevaluate the requirement for the third data mode that combines five low bit rate data streams

5) Possible reevaluation of the dual frequency - two links up and down approach - for example a single link may be cheaper because the multiplexing - de-multiplexing system is simpler than a two channel rf system.

It is recommended also that information from Reference 1 be used to derive a tentative baseline for the AAP-Intelsat IV terminal and that the proposed Data Mode 3 be added to this baseline after evaluation of requirements for this mode are complete. For convenience, Tables III and IV from Reference 1 are attached. It should be noted that no margin is included in these terminal parameters and real world implementation could expand these requirements. They do assume, however, that operation with the Intelsat IV is at the beamedge of its global coverage horn where satellite gain is the lowest. Operation at this point on the Intelsat antenna will occur for short periods only during a revolution of the SWS.

R L Selden

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Attachments
Tables III and IV

REFERENCES

1. Chen, R. K. "AAP Terminal Requirements Using Intelsat IV for Communications Relay", Memorandum for File, September 24, 1969.

TABLE III

AAP COMMUNICATION PERFORMANCE REQUIREMENTS-ASSUMED

Function	Baseband Performance	Modulation	S/N Req. Pre-detection	RF Bandwidth	C/No Req.
Voice (up and down links)	T/N=20 dB (Tone to noise ratio)	FM	10 dB	15.5 kHz	52 dB-Hz
Up-data (up-Link) (1.0 kbps)	10^{-6} BER	PSK/FM	10.0 dB	10 kHz	50 dB-Hz
Telemetry (down-Link)					
-51.2 kbps	10^{-4} BER	PSK	11.4 dB*	Bit-Rate Bandwidth	58.5 dB-Hz
-72 kbps	"	"	"	"	59.9 dB-Hz

*3 dB margin included

TABLE IV

TYPICAL PARAMETERS FOR AAP TERMINAL

FUNCTIONS	5.5 FT. S/C ANTENNA		11 FT. S/C ANTENNA	
	$(EIRP)_{SC}$ (dBW)	TRANSMITTER POWER (WATT)	$(EIRP)_{SC}$ (dBW)	TRANSMITTER POWER (WATT)
Voice	46.9	16.2	46.3	3.5
TLM				
•51.2 kbps	53.4	72.5	51.8	16
•72 kbps	54.8	100	54.2	22

Assume: 3dB Transmitting Line Loss
6dB Noise Figure Tunnel Diode Amplifier Mounted Near Antenna Feed

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